To Burn or not to Burn? A Description of the History, Nature and Management of Bushfires within Ku-Ring-Gai Chase National Park

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The January 1994 bushfires in New South Wales has once again brought the issue of bushfire management within natural areas into sharp focus. This paper analyses the bushfire history of Ku-ring-gai Chase National Park (1943–1994) from fire records maintained by the National Parks and Wildlife Service. The patterns of bushfire occurrence for the Park are discussed. The management policies of the National Parks and Wildlife Service for this area are also outlined. The impact of the January 1994 wildfires on the Park is assessed, particularly in relation to the effectiveness of prescribed burning on wildfire control in the Warringah and Pittwater areas. Prescribed burning in the Park was effective in assisting with the containment of the 'Cottage Point' wildfire despite the extreme fire weather conditions experienced. The management policies adopted by the Service were effective in protecting important catchments, important animal species and maintaining refuges from which animals and plants can recolonise burnt patches. The importance of maintaining accurate and relevant fire history records is emphasised.

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KEYWORDS: Ku-ring-gai Chase National Park; bushfire history; January 1994 wildfires.

INTRODUCTION

Gill (1975) describes fire regimes in terms of the combined effects of bushfire frequency, intensity and season of occurrence. Gill and Bradstock (1993) add that the spatial distribution of bushfires, or the 'patchiness' of bushfires, is also an important component of the bushfire regime. Bushfires are an important agent of change in the bushland of south-eastern Australia. The composition and structure of natural plant and animal communities may be altered as a result of imposed changes in the fire regime.

For example Catling (1991) found that the infrequent occurrence of intense wildfires favours the development of a dense understorey which is favoured as habitat by native vertebrate fauna. Catling (1991) also found that frequent, low-intensity burns in autumn will disadvantage native mammal species and advantage many exotic species.

Fox and Fox (1986) report that a shrubby woodland site on the New South Wales mid north coast which had burnt twice within 12 years had significantly more plant species and higher shrub densities than a similar site burnt only once in the same period. Fox (1988) also found differences in plant species richness and diversity and community structure in a mid-north coast open forest at different ages since the last fire. Similarly Morrison et al (1995) found that fire frequency (i.e. time since last fire and inter-fire period) accounted for about 60% of the floristic variation in dry sclerophyll vegetation on the NSW Central Coast. They proposed that variability in the inter-fire period will

lead to a greater diversity of plant species within a particular community. Christensen and Kimber (1975) also reported that changes in understorey composition may be brought about by alterations to fire frequency.

Ridley and Garner (1961) report the conversion of large areas of sub-tropical rainforest in Queensland to lantana groves following frequent burning. Rainforest areas are particularly vulnerable to transformation following bushfire and are frequently converted to eucalypt forest after intense bushfires have burnt through them in drought conditions. After long bushfire free intervals (ie > c.150 years) these same areas may convert back to the rainforest that once existed there (Ashton 1981, Hopkins 1981, Smith and Guyer 1983).

The application of different bushfire regimes will also impact on soil fertility and structure. Reduced cover as a result of frequent bushfires or extensive high intensity bushfires will lead to the mobilisation of soil and nutrients and greatly accelerate soil erosion (Lamy and Junor 1965a and 1965b, Harwood and Jackson 1975, Henry 1977, Blong et al. 1982, Adamson et al. 1983, Atkinson 1984). It is reasonable to assume that a close inter-relationship exists between the effects of fire on inducing changes to soil fertility and structure and to subsequent changes in the composition and structure of plant and animal communities. Understanding the spatial and temporal distribution of bushfires and prescribing fire regimes to meet management objectives is therefore a very important task within conservation reserves.

Ku-ring-gai Chase National Park is similar to many other conservation reserves on the fringe of Sydney. The Park is comprised of flammable vegetation types and steep slopes surrounded by urban and rural development. The Park has a history of frequent and extensive wildfires. The Park also contains species which are sensitive to the application of certain bushfire regimes. Management of the Park has to be undertaken in a way which is sensitive to the protection of neighbours and Park visitors but which is also ensures that species and natural communities are conserved.

This paper examines the approach taken by the New South Wales National Parks and Wildlife Service (NPWS) in fire management within the Park. The history and occurrence of bushfires within the Park is analysed and the management response of the NPWS is summarised using specific examples of the approach taken in the management of significant species and landscapes. The success of this approach and the implementation of prescribed burns within the Park over the last five years is assessed in relation to the impact of the January 1994 wildfires.

NSW NATIONAL PARKS AND WILDLIFE SERVICE

The NSW NPWS has statutory responsibility *(inter alia)* for the establishment of national parks and nature reserves; and within parks and reserves for the protection of all plants, animals and landscapes including wilderness areas and the provision of facilities for the use, appreciation and enjoyment of those areas. The Service is also responsible for the protection and care of fauna; the protection of native plants and the care, preservation and the protection of Aboriginal relics and places throughout NSW.

The Service has a statutory responsibility under the Bush Fires Act (1949) for minimising the risk of escape of fires from areas under its care, control and management. The Service co-operates with other fire authorities and land management agencies in bushfire suppression, mitigation and prevention activities within local government areas and as such contributes to the development and implementation of fire operations and fuel management plans under Section 41AB of the Bush Fires Act 1949.

The management of bushfire within national parks and nature reserves is guided by the objectives and strategies identified within plans of management prepared in accordance with Section 72 of the National Parks and Wildlife Act 1974. Section 72 prescribes that for national parks and nature reserves the Service shall have regard (inter

alia) to 'the protection ... against fire and erosion', 'the protection of special features', 'the preservation ... as a catchment area' and 'the conservation of wildfire'.

If no plan of management has been prepared, then bushfire management policies and procedures are specified within non-statutory NPWS bushfire management plans. These same policies and procedures are also negotiated with Bush Fire Management Committees and are adopted for Parks and Reserves within fire operational and fuel management plans prepared under Section 41AB of the Bush Fires Act 1949.

The NPWS must also consider the relevant arrangements made at Commonwealth and State Government level for protecting the environment. These include international treaties, conventions and inter-governmental agreements to which the Commonwealth and NSW State Government are signatories such as the Convention on Biological Diversity and the Inter-Governmental Agreement on the Environment. These conventions and agreements commit the NSW Government to protecting biological diversity, maintaining ecological processes and systems and integrating environmental considerations into all levels of Government decision-making respectively. These conventions and agreements must be taken into account in the planning and implementation of fire management activities.

KU-RING-GAI CHASE NATIONAL PARK

Ku-ring-gai Chase National Park is an area of about 14,700 hectares on the northern outskirts of Sydney. The Park is part of a complex of national parks and nature reserves on the sandstone plateaux surrounding Sydney (eg Blue Mountains National Park, Brisbane Waters National Park, Marramarra National Park, Muogamarra Nature Reserve etc). Responsibility for the management of the Park is vested in the Director-General of the National Parks and Wildlife Service. The objectives of management for the Park are outlined within an adopted plan of management and are consistent with objectives defined in Section 72 of the National Parks and Wildlife Act 1974.

The Park is part of the Hornsby Plateau and is bordered by the drowned river valleys of the Hawkesbury River and the urbanised shale plateaux and ridges of the northern suburbs of Sydney. The topography is characterised by sandstone slopes averaging 10–15° over an elevation range of about 200 metres and plateaux with large outcrops sandstone outcrops covering >50% of the surface area. The sandstone soils of the Park are shallow and infertile, have a low water capacity and are subject to extreme sheet and gully erosion following disturbance (Chapman and Murphy 1989).

The slopes and ridges are covered with a dry sclerophyll vegetation with shrubland, woodland and open forest structural types being the most common. In narrow gullies on Narrabeen Shales and in some of the small volcanic diatremes within the Park, a more mesomorphic vegetation occurs under tall open forest and closed forest structural types. Small areas of sedgeland are found in the hanging swamps of Lambert Peninsula (Thomas and Benson 1985).

Fine fuel types are differentiated mainly on the basis of vegetation structure and density and accumulate quickly in the first 8 years following a fire. From 8 to 15 years, fuels accumulate more slowly and after 20 years, fuel loads appear to stabilise. Maximum fine fuel levels occur in the shrubland fuel type with as much as 35 tonnes/hectare being recorded in 25 year old vegetation (Conroy 1993).

The bushland within and surrounding the Park is one of the most fire prone areas in Australia with very high fine fuel potential, very flammable fuel types, steep slopes, regular occurrence of extreme fire danger weather and large areas of urban-bushland interface. The Park has a total linear boundary of c.116 km. Fifty-six kilometres of this boundary is urban-park interface with c.2000 residential homes being situated on or near the Park boundary.

BUSHFIRE IN THE PARK

Prehistoric Records

Kodela's (1984) study on pollen and charcoal deposits in a 6,000 year old soil profile within a hanging swamp at Salvation Creek on the Lambert Peninsula in Ku-ring-gai Chase NP, revealed widely fluctuating charcoal inputs. Major peaks in charcoal influx, representing high fire activity (either due to high fire frequency and/or high intensity fires) were believed to have occurred around 300, 400, 1300, 1700 and 2300 (main peak) years before present. Low fire activity was recorded approximately 800 and 4200 years before present. Kodela (1984) did not find any evidence of vegetation change with increasing fire frequency.

Martin (1971) recorded pollen of the rainforest genera *Ackama, Nothofagus* and *Rhodomyrtus* in 4,000 year old sediment from the nearby Dee Why Lagoon. These species are fire sensitive and are now not represented in the area. It is possible that fire and/or climatic changes led to these species becoming locally extinct.

Evidence of Aboriginal occupation and burning practices in the area comes from a variety of sources. Hughes and Sullivan (1981) found evidence of increased firing of the landscape over the last c.4000 years in rock shelters in the Mangrove Creek catchment near Sydney, and suggest that this was closely associated with the Aboriginal occupation of the area. They believed that Aboriginal fire regimes lead to episodic and severe erosional and depositional events which greatly exceeded those levels that might be expected under natural firing regimes. Head (1989) however casts some doubt over these conclusions suggesting 'this need not signify anything more than disturbance at the very local scale'.

Historic Records

Clark and McLoughlin (1986) believe that on the basis of available historical and biological evidence from the north shore of Sydney, that Aborigines burnt the bushland frequently. They state that it is likely that burning was more frequent on the shale ridges (c.1–5 year intervals) than on the adjacent sandstone slopes (c.7–15 year intervals). The main evidence to support this notion comes from the accounts of explorers (eg the First Fleeters: Hunter, Phillip and Worgan) of the North Shore of Sydney in the nineteenth century and their descriptions of the nature of the vegetation and of Aboriginal land management practices at the time.

Extreme wildfire events have been recorded in the Sydney Region in 1888, 1928–29, 1936, 1938–39, 1944–45, 1946–47, 1951–52, 1957–58, 1964–65, 1968–69, 1974–75, 1977, 1980–81 and 1983 (Cheney 1979, Cunningham et al. 1994).

Ku-ring-gai Chase Trust records (prior to 1967) and NPWS records (since 1967) reveal extensive wildfire events within the Park during the same time periods, that is 1943, 1946, 1951, 1957/58, 1965, 1967/68, 1977, 1979, 1980, 1983 and 1994. Table 1 shows the location and approximate size of large (ie >500ha) recorded wildfires in the Park over the last 51 years.

Vines (1974) stated that 'severe forest-fire seasons' in southern Australia occurred every 13 years and were associated with regular drought periods. He suggested that for any given region, droughts and possible bushfire seasons are chronologically related to distinctive weather patterns for the area which are quasi-periodic in nature. Most of the major wildfires within the Park (eg Table 1), have coincided with long extended drought periods (ie 1957–58, 1967–68, 1979–83, and 1993–94) and have occurred where fuels had accumulated over large fire prone areas for periods up to and exceeding 10–12 years.

The frequency and extent of wildfires in the Park in the late fifties and sixties was of great concern to the Trustees of the Park and to local fire authorities (Anon 1967). A special study of the impact of these fires was commissioned by the Park Trust (Lamy and Junor 1965). They reported that 'intensely hot fires have repeatedly ravaged this catch-

ment (Porto Bay) and a recent fire caused great damage and destruction of tree cover'. They also stated 'Accelerated erosion has occurred in all catchments of Ku-ring-gai Chase over the past fifty years and, in the main, this can be directly attributed to the damage caused by frequent severe fires'. Similar problems were encountered in nearby areas such as the McDonald River Valley (eg Henry 1977).

TABLE 1

Major wildfires in Ku-ring-gai Chase NP 1943/44–1993/94

00/00/1943	Lambert Peninsula	3,500
28/01/1946	Duckholes/Ingleside	4,000
00/00/1958	Refuge Bay/Lambert Peninsula	4,600
14/11/1965	Refuge Bay/Lambert Peninsula	3,000
27/11/1968	Nth Turramurra/St Ives Chase	850
01/10/1971	Wahroonga/Nth Turramurra	518
16/12/1979	Nth Turramurra/Terrey Hills	5,200
01/11/1980	Shark Rock Ridge/Berowra	1,226
08/01/1983	Govett Ridge/Ten Bob Ridge Cowan	1,400
09/01/1983	Mt Colah	1,320
23/12/1990	Mt Colah/Nth Turramurra	935
07/01/1994	Cottage Point/Lambert Peninsula/Terrey Hills	7,110

From the early 1970's through to the 1980's, reports of an increasing 'shrubbiness' in the nature of the vegetation in the Park was reported. This increased shrubbiness was generally attributed to the reduced frequency of extensive bushfires caused by strategic fuel management programmes and the increased effectiveness of fire suppression and fire prevention programmes. Photographic evidence (ie Park records of oblique 1900–1910 photographs and aerial photographs from 1946–1994) and accounts of bushwalkers and scout leaders who have used the Park over the last 50 years confirm this observation. For example Mr Fred Matthews of Waitara (*pers. comm.*). has used the Park with his scout troop for over 30 years and states that it was possible to walk from one rock outcrop to another within the Park with little difficulty in the 1940's, 50's and 60's. However in the 1980's and 1990's the vegetation has become so dense in some areas that to walk along some of the same plateaux and ridges becomes a real struggle with dense shrubs being encountered all of the way.

This evidence is also consistent with accounts from other areas in the Hawkesbury-Nepean River catchment. Many of the land-owners from the 1940–50's who are still living in the area (eg Woodbury family from Spencer on the Hawkesbury River) report the increased 'shrubbiness' in the bush over the last 50 years and the 'unfortunate' decline in some of the more attractive flowering plant species such as Christmas Bells (*Blandfordia nobilis* Sm.), Flannel Flowers (*Actinotus helianthi* Labill.) and Native Rose (*Boronia serrulata* Sm.) as a result of a decrease in bushfire frequency. Generally a more open understorey and greater ease and comfort of bushwalking is consistently reported by bushwalkers and neighbours who used the Park in the 40's, 50's and 60's (*pers. comms.*).

Experienced volunteer bush fire brigade members from the Coal and Candle VBFB in the Warringah Council area (*pers.comm.*) believe that the installation of authorised fireplaces in the West Head and Duckholes area of the Park in the early to mid-1970's had a very significant impact on reducing the number of wildfires caused by campfires in the Park. Cheney (1979) supports these observations arguing that the fre-

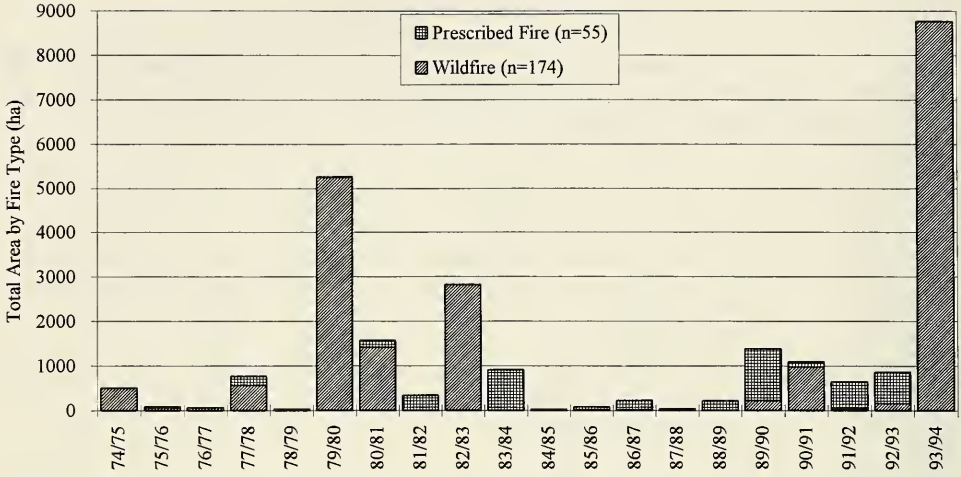

Fig. 1. Total area burnt by bushfire type (n = 229) within Ku-ring-gai Chase NP (1974–94).

quency of large fires in southern Australia has probably decreased recently as a result of greater management and control of bushland, the impact of fire prevention programmes, a decrease in the number of ignition sources, more efficient and effective suppression of fires and increasing fuel management and control by land management authorities. Although conjectural and anecdotal, this information is valuable in understanding the relationship between fire regimes and the landscape and for understanding changes over time in the nature of the vegetation.

Total Area Burnt by Fire

The total area burnt by fire in the Park over the last 20 years is shown in Figure 1 and Figure 2. The total area burnt within the Park over the last 20 years is in excess of 25,000 hectares (ie c. 1,250 $ha.yr^{-1}$) with a large number of fires burning the same area more than once. Unfortunately, reliable fire frequency data for the Park are not yet available to present any analysis of this.

Over the last 20 years, large wildfires (ie >1000 hectares) were recorded in the Park in 1979, 1980, 1983 and 1994. These periods coincide with extended droughts within the Sydney Region. Prescribed burns have not contributed significantly to the total area burnt. At the end of 1993/94, prescribed burning had contributed only 18.25% of the cumulative total area burnt. The average size of recorded wildfires within the Park over the last 20 years (n = 174) is 120.3 ± 782 hectares. In the period before 1974, the average size of recorded wildfires (n = 122) is 103.9 ± 475.6 hectares. The average size of prescribed burns in the last 20 years (n = 55) is 86.1 ± 28.9 hectares. There are no records of the area burnt in prescribed burns prior to 1974.

Cause of Wildfires

Arson is thought to account for 40.8% of the total number of wildfires occurring in Ku-ring-gai Chase NP (Figure 3). If combined with the major proportion of wildfires of 'unknown' cause then an estimate of c.57% of all wildfires can be attributed to arson and related causes.

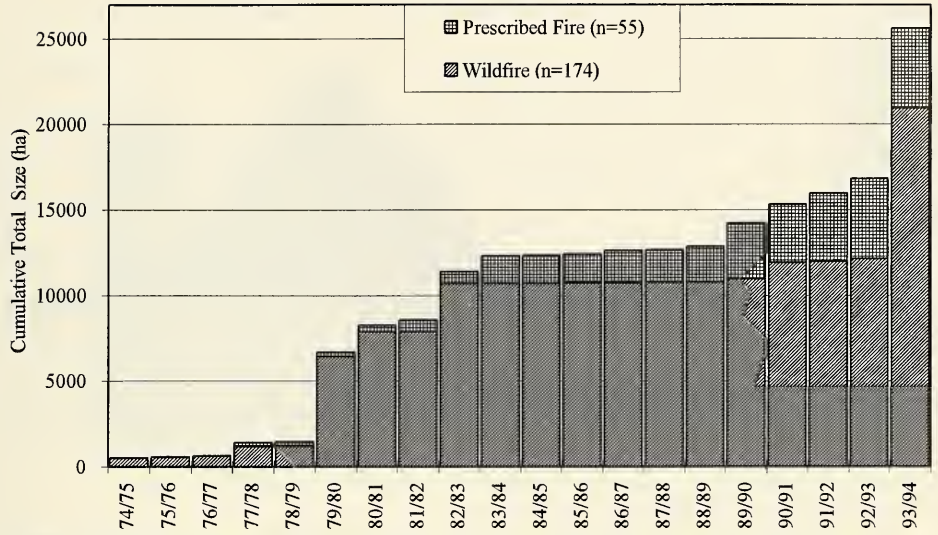

Fig. 2. Cumulative total area burnt by bushfire type (n = 229) within Ku-ring-gai Chase NP (1974–94).

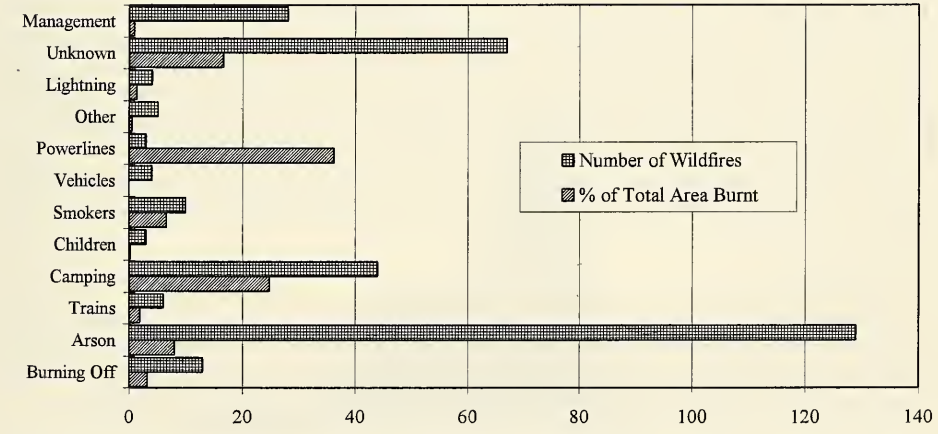

Fig. 3. Total number and % of total area burnt by cause (n = 316) within Ku-ring-gai Chase NP (1943–94).

Natural sources of ignition (ie lightning) account for only 1.3% of all wildfires and 1.3% of the total area burnt by wildfires over the recorded fire history of the Park (ie 51 years) This is because storms of this type, on or near the coast, are usually accompanied by heavy rainfall. This is quite different in the Blue Mountains area (Conroy and Gellie 1987) where lightning may account for up to 28% of wildfire ignitions and where as many as 25 wildfires may be caused by the one thunderstorm event (N. Gellie NPWS *pers comm*).

Although powerlines were not a significant cause of wildfires during the period, comprising only 0.9% of the total number of wildfires, they are significant in terms of the total area burnt, comprising 36.2% of that total. While the average size of an arson fire in the Park is 97.8 hectares, the average size of a powerline fire is 441.2 hectares (Figure 3). Powerline fires are caused by electrical transmission lines striking together in high wind conditions which results in hot metal and insulation material dropping to the ground.

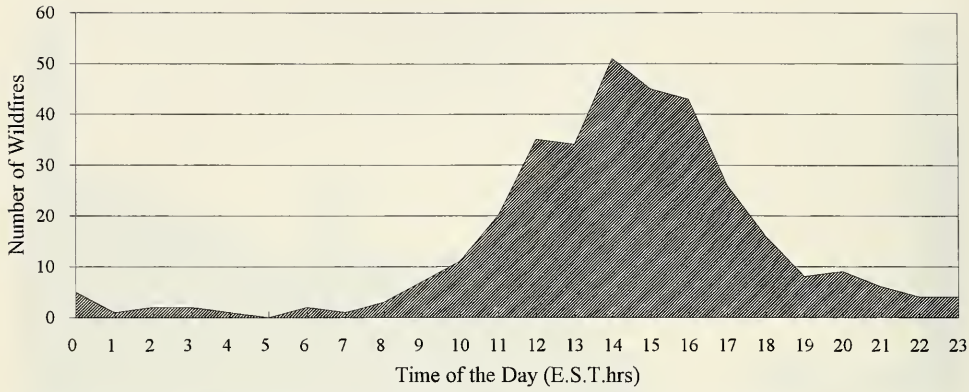

Fig. 4. Number of wildfire ignitions by time (EST) of the day (n = 260) within Ku-ring-gai Chase NP (1943–94).

Time of Ignition of Wildfire

Records of wildfires in the Park (1943–1994) where time of ignition was recorded (n = 260) were analysed. The time of the day when most wildfires are ignited is between 1300hrs and 1600hrs, with 43.8% of all wildfires occurring during this period (Figure 4). The large majority (ie >75%) of wildfires being ignited between 1000–1800hrs. Wildfire ignitions which were recorded between 2300–0100hrs are related to the practice on New Years Eve, of firing boatflares from boats moored in Cowan Waters and Pittwater across the Park on the stroke of midnight. The flares ignite fires in Park areas which are usually difficult to access and at that time of the night, difficult to resource with firefighters.

Time of day and wildfire ignition are likely to be related through a variety of factors including relative humidity and associated fine fuel moisture content. It is very likely that societal routines (eg school times and shift hours) would also influence these figures.

Day of the Week

Wildfire analysis by day of week shows some interesting trends. Most wildfires are ignited on Sundays (22.6%) and Mondays (17.6%) (Figure 5). This trend may be related to the greater number of people using bushland for recreational purposes on weekends and public holidays and to the number of people who leave campfires unattended.

Month of Occurrence

The bush fire danger period in New South Wales is usually 1st October to the 31st March unless modified as a result of local weather conditions. The trends of recorded wildfire occurrence by month within Ku-ring-gai Chase NP are illustrated in Figures 6 and 7. The data show that in terms of area burnt, the most important period is from October to January. There is a large drop in the recorded area burnt by wildfire in February. This may be explained by the slightly wetter conditions which exist in the Sydney Region in February (average wildfire size is 7.6 hectares) and as result of societal factors such as the end of the NSW school Christmas holiday period.

The trend in the number of recorded wildfires by month shows that the six-month period August–January is the most important period for wildfire occurrence with 80% of the total number of recorded wildfires. However the average size of recorded wildfires for August (29.6 ha), September (27.3 ha) and October (27.3 ha) is significantly less than the next period of November (153.2 ha), December (127.9 ha) and January (462.2 ha).

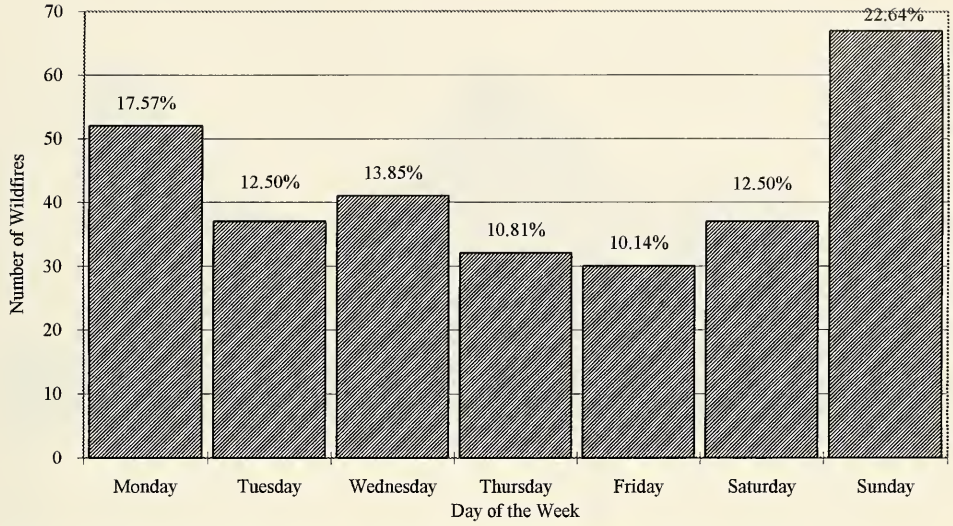

Fig. 5. Number of ignitions by day of the week (n = 296) within Ku-ring-gai Chase NP (1943–94).

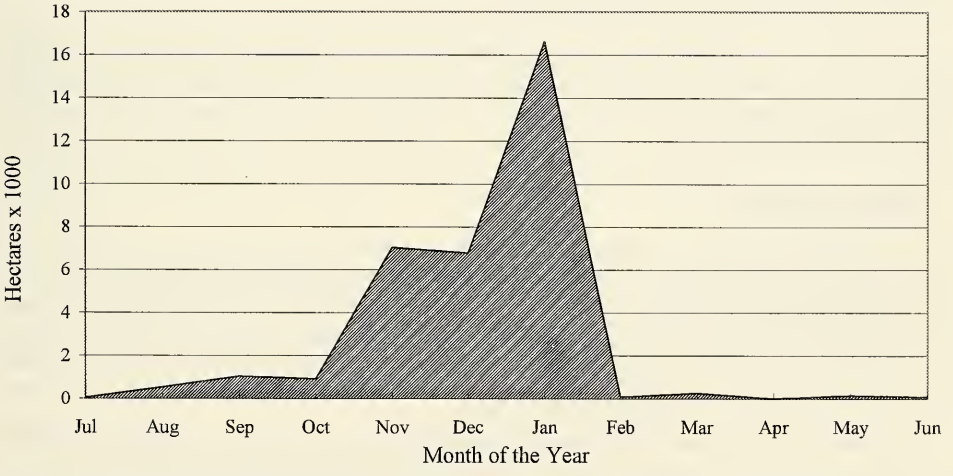

Fig. 6. Total area burnt by month of the year (n = 296) within Ku-ring-gai Chase NP (1943–94).

Number of Wildfires by Size Class

The wildfire data (Figure 8) for Ku-ring-gai Chase NP show that a large proportion of wildfires (69.6%) do not exceed 10 hectares in size, while 86.8% of wildfires do not exceed 100 hectares in size. Trends in the size of wildfires within discrete areas can be used as a very useful performance measure of the effectiveness of strategic fuel management works and the effectiveness of the total wildfire suppression response (ie the detection and suppression of wildfires).

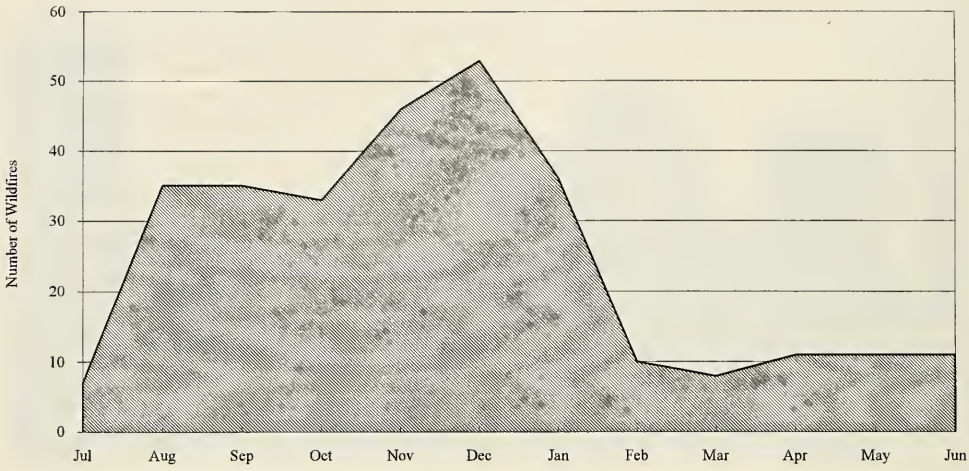

Fig. 7. Number of wildfires by month of the year (n = 296) within Ku-ring-gai Chase NP (1943–94).

Bushfire Management Considerations

The NSW National Parks and Wildlife Service has developed bushfire management policies for Ku-ring-gai Chase National Park (NPWS 1994) which take into account the fire history of the Park as described above and those special features of the Park which may be sensitive to changes in fire regimes. Some of these special features are summarised below.

Grevillea caleyi R.Br.

Grevillea caleyi is an endangered plant (Briggs and Leigh 1988) which is restricted to a 6 x 6 km area centred on the northern Sydney suburb of Terrey Hills (Scott et al. 1995) and which has a some small populations within both Ku-ring-gai Chase and Garigal National Parks. It is a fire sensitive species which relies on germination from a soil seedbank to recover after fire. Senescence is high in populations of *G. caleyi* which are older than about 12 years. Repeated fires at intervals of less than 8 years will cause local extinction of *G. caleyi* (Scott et al. 1995).

Scott et al (1995) also identified the potential negative impacts caused as a result of creating islands of unburnt habitat in areas containing rare or threatened plants, particularly where those species are also obligate seeders. For example seed predators may be drawn to an unburnt site and therefore consume most of the crop of seed produced for that year. *G. caleyi* does not produce a great amount of seed per plant with only 3% of flowers producing viable seed. The seed is relatively long-lived with a half-life of about 7.6 years but 82–92% of the seed is consumed by seed predators. Therefore it is important to minimise the impacts of seed predators on the plant after bushfires.

The NPWS fire management policies prescribe a fire regime for plant communities known to contain *G. caleyi*, which attempts to ensure that fire frequency is variable and where the average fire frequency is less than one fire every 12 years. Populations *of G. caleyi* are also burnt if surrounding areas are burnt and the average fire frequency at the site is >12 years. *G.caleyi* seedlings have been recorded in good numbers in many of the previous known locations which were affected by the January 1994 wildfires.

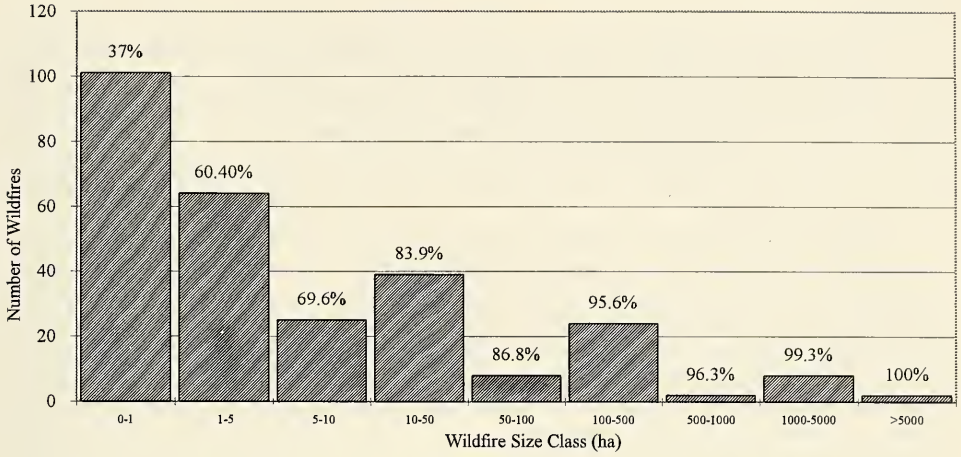

Fig. 8. Number of wildfires by size class (n = 273) showing cumulative total (%) for each size class within Ku-ring-gai Chase NP (1943–94).

Koala Populations

Koalas have been recorded within the Park at various locations (eg West Head, Duckholes, Akuna Bay and Cottage Point). Wildfires have been implicated in the decline of koala populations in New South Wales (Lunney et al. 1988). Tilley and Uebel (1988) describe the effectiveness of the use of selective strategic burning and aerial ignition methods for hazard reduction in assisting to mitigate the effects of wildfires on koala populations in the Upper Nepean catchment area. Koalas appear to be particularly vulnerable to high intensity fires and in the long-term, to the effects of frequent low intensity fires on their habitat as a result of the impacts on soil fertility and food tree species survival.

NPWS Park fire management policies prescribe measures which aim to reduce the risk of high intensity bushfires in areas where koalas have been recorded by strategic fuel reduction burns. This strategy proved to be very effective during the January 1994 wildfires, with known locations of koalas being protected from extreme wildfire behaviour as a result of reduced fuel levels in surrounding areas.

Sensitive Slopes

The major landscape unit of the Park is the Hawkesbury landscape type (after Chapman and Murphy 1989) which consists of shallow discontinuous lithosols or siliceous sands, yellow earths, earthy sands and yellow podzolic soils. This soil type is highly susceptible to concentrated flow erosion and sheet erosion especially when the organic matter is removed by intense bushfires.

Park fire management policies specify that in areas containing a combination of steep slopes and sensitive soils, the application of bushfires should ensure that adequate levels of cover are maintained over slopes to minimise soil erosion within those catchments. For example fuel management burns are staged over several years in fire sensitive catchments to ensure that sufficient vegetation cover is available to reduce the risk of concentrated flow and sheet erosion. The intensity of the burns is also managed to increase the patchiness of vegetation cover in these catchments which further reduces the risk of erosion.

Rainforest

The margins of rainforest with eucalypt forest may be sharp or there may be an ecotone depending on factors which include the time since the last fire and the average fire interval for the area. Rainforest boundaries are often interpreted as advancing at the expense of the eucalypt forest due to an absence of disturbances such as fire (Smith and Guyer 1983). Although rainforest fires have been well documented, rainforests nevertheless provide effective barriers to the progress of wildfires except under the most extreme fire weather conditions.

Rainforest vegetation occupies a very small area (<1%) of the Park (Conroy 1987). It is distributed in very narrow gullies and in volcanic craters (eg Campbells Crater) which are extremely vulnerable to intrusion by wildfire and colonisation by exotic species. Many fire sensitive plant species are only known from these rainforest communities. These species include *Abrophyllum ornans, Cryptocarya spp, Dendrobium striolatum, Polyosma cunninghamii* and *Toona australis*. The NPWS policies are aimed at encouraging the growth of rainforest areas to their maximum available limit within the Park. The NPWS therefore attempts to minimise the impact of bushfires on the ecotonal area of rainforests. For example it is tempting to use rainforest boundaries as natural boundaries for wildfire control and prescribed burns because it is safer and cheaper to do so. The NPWS policies suggest that this is not acceptable and that the extra effort should be taken to avoid impacts on rainforest ecotones.

The policies also state that some areas will be managed to increase opportunities for whole catchments to be kept in an old age class condition (eg Smiths Crater, Campbells Crater and Cicada Glen Creek catchments.)

Old Growth Vegetation

There are very few areas of old growth dry sclerophyll vegetation remaining within the Park or for that matter within the Sydney Region generally. In 1986, only 25% of the area of the Park was older than 21 years (Conroy, 1987). In 1994, following the January fires this figure has declined to about 1% (*pers.obs.*). A similar situation occurs in other conservation areas on Hawkesbury Sandstone soils.

The Park fire management policies state that it is desirable to have at least 50% of the most common plant communities in an old age class condition (ie >20 years in age). This is because of the special needs of some animal species for dense shrub and herb cover (eg lyrebirds, whip birds, pheasant coucals, red-necked pademelons, bandicoots etc), to serve as scientific benchmarks, as a means of implementing the 'precautionary principle' in accordance with Clause 3.5.1 of the Inter-Government Agreement on the Environment and to give managers flexibility in the future management of the Park.

The policies also state that some areas will be managed to increase opportunities for whole catchments to be kept in old age class condition (eg Mt Murray-Anderson, Shark Rock Ridge, Windybanks Ridge). These policies are taken into account when prescribed burns are being planned and during the development of wildfire control strategies.

Special Habitats

There are a few very special sites within the Park that contain vegetation communities which are of conservation and scientific interest. These include sites on volcanic dykes and diatremes (eg West Head Dyke, Campbells Crater and Smiths Crater) and vegetation communities and plant species on sandstone rock outcrops and gnammas (eg *Kunzea rupestris* Blakely and *Micromyrtus blakelyi* J. Green).

These sites are uncommon in Sydney Region and could be irreversibly damaged by the application of the wrong type of fire regime. A conservative approach has been adopted by the Service in managing these plant communities (ie IGAE precautionary

principle). Park fire management policies specify that these sites will not be subjected to prescribed burning and that where it is possible and cost-effective to do so, wildfires will be prevented from burning them until the impacts of fire on them are known with some certainty. The nature of wildfires in the Park makes it unnecessary to burn these communities deliberately as that would only reduce future management options.

Prescribed Burning Strategies

Strategies for prescribed burning within the Park have been developed largely from an understanding of wildfires over the last 20–50 years and attempts to minimise unacceptable impacts on species, communities and landscapes from inappropriate fire regimes.

Volunteer bush fire brigades (VBFB's) and the NSW Fire Brigades (NSWFB) concentrate on reducing hazards in close proximity to assets at risk usually on vacant crown lands and private property. Generally NPWS concentrates on Park strategic wildfire control burns; while VBFB's and NSWFB's concentrate on 'off-Park hazard reduction burns'. This arrangement reflects relative funding arrangements, availability of resources of the various organisations and statutory responsibilities. However, there are also many examples where resources and responsibilities are shared to achieve regional fire management objectives and to overcome individual agency funding or resourcing problems.

There had been 30 recorded prescribed burns within the Park in the five years immediately preceding the January 1994 wildfires. Of these 23 (76%) were located on Park boundaries. The total area burnt was 2950 hectares of which 2942 hectares were within the Park. Therefore 19.6% of the total Park area had been treated in prescribed burns in the 5 years prior to the January 1994 wildfires.

A total of 1404ha or 9.4% of the Park had also been affected by wildfires (n = 44) in the previous five years. Therefore 26% of the total area of the Park contained fuel which was less than 5 years old. A large proportion of this area was located on Park boundaries and located in areas affected by the January '94 wildfires.

Many of the prescribed burns over the previous five years had been undertaken to reduce fire threats to neighbouring lands, protect species habitats, protect old growth vegetation and to provide a diversity of age classes in the more common plant communities.

Effect of Prescribed Burning on Containing Wildfires

Buckley (1992) stated that fuel should be reduced across more than 50% of the area of a site to be effective under very high to extreme fire danger conditions. Fuel reduction burning in coastal forests of East Gippsland covering more than 50% of the area of a site provided excellent protection against wildfire spread for at least one-and-half years, but the effectiveness of these burns reduced progressively over a seven year period depending on the fire weather conditions.

The value of prescribed burning in assisting with the containment of wildfires is often questioned and some argue that prescribed burning is of little use in wildfire control. This is not the case (*pers.obs*). There are many examples in the Hornsby and Warringah areas where wildfires have been contained or where the impact of wildfires on assets, species, scenic resources, heritage items and landscapes has been greatly reduced as a result of prescribed burns. Recent examples occurred at Berowra (1985), Cowan (1990), West Head (1994), Belrose (1994), Duffys Forest (1994) and St Ives (1994) where wildfire runs were effectively contained under extreme weather conditions as a result of prescribed burns.

Problems with Implementing Prescribed Burning

Johnson (1984) summarises the many problems involved in implementing prescribed burns. Among these were regulatory constraints (eg clean air legislation), the

costs associated with risk of fire escape during high fire danger days (eg in Victoria, December 1994), the costs and risks associated with postponement of prescribed burning programmes due to poor weather conditions, the risks to the safety and welfare of firefighters and controversy over environmental impacts.

Gill et al. (1987) also discuss the difficulties associated with selecting appropriate weather conditions to undertake prescribed burning. They estimated that at fuel weights of 10–40 t/ha^{-1}, optimal weather conditions (ie from Melbourne data) for prescribed burning occurred on only 11.2 days per annum. They state 'it is probable that several years may pass without there being days optimal to prescribed burning so that fuel weight continues to rise ...'. These difficulties are very real to managers and firefighters in the Sydney Region with a large proportion of planned burns being cancelled due to unsuitable weather conditions. Some prescribed burns in the Park (eg 1984 at West Head) and in the nearby Garigal NP (eg April–June 1994 at Middle Harbour Creek) have had to be re-scheduled on four separate occasions over a period of several months as a result of unsuitable weather conditions.

Reliance of land management authorities in the Sydney Region on the support from volunteer bush fire brigades who are mostly available on weekends only, further compounds this problem. It is common for a large number of prescribed burning proposals to be cancelled at short notice due to either lack of available resources, lack of suitable weather conditions or to air pollution problems. For example 'No-burn notices' issued under Section 24A of the Clean Air Act (1961) were responsible for cancellation or modification of prescribed burns on 7/05/1992 at Cottage Point in Ku-ring-gai Chase NP; 27/08/1991 at DeBurghs Bridge in Lane Cove NP and more recently on 17/08/1994 at Cattai NP.

Local community groups have also sometimes thrown the prescribed burning programme into disarray. For example at Elvina Bay in 1992 residents were polarised on the issue of whether a burn proposed by NPWS and local VBFB's should proceed. The residents believed that an alternative method of hazard reduction (manual hazard reduction) should be trialled by them. This was later done and proved very effective in this situation. Community opposition to burning as a means of reducing hazards is a common problem throughout the Sydney Region and needs to be managed more effectively.

One of the problems of fire management in the Park, is that while it is generally not possible to burn an area more frequently than about once every five years during the prescribed burning season (ie March–August), it is possible for a wildfire burning under extreme weather conditions to run through the same area with sufficient intensity to cause property damage. This was seen in a number of localities in the Warringah/Pittwater area during January 1994 (eg Cottage Point, McCarrs Creek and on the Centre Trail in Ku-ring-gai Chase NP) where the Cottage Point fire failed to be contained by prescribed burns implemented between 2 and 5 years ago. However the intensity of the fire was reduced as it burnt through lighter fuel loads. Only those prescribed burns which had been implemented in the last 18 months were effective in containing the Cottage Point wildfire. Similar problems were encountered in other areas during the January' 94 wildfires (eg at the Howes Valley, Lane Cove and Hornsby fires).

CONCLUSION

To burn or not to burn? The well documented fire history of Ku-ring-gai Chase National Park demonstrates that until the 1970's, wildfires were more frequent and were widespread throughout the Park. This fire regime resulted in a depleted shrub understorey, the exposure of large amounts of bare soil and subsequent sheet erosion and sedimentation of the waterways. It is likely that this scenario applied to many of the bushland areas around Sydney.

It seems that the implementation of strategic prescribed burns, the better resourcing of volunteer bush fire brigades and NPWS, fire prevention and detection programmes and the installation of authorised fireplaces did much to bring this situation under control.

After 1970, fire suppression became more effective and recreational use of the Park and other fire ignition causes were better managed. Prescribed burns and fire trails were placed in strategic areas which reduced fire spread and wildfires became less frequent but more intense. A fire frequency of 10–15 years for most of the Park particularly the ridges and upper slopes is apparent over the last fifty years. The effect of a reduced fire frequency and the resulting higher fire intensities has extended the age of vegetation in many areas and has thereby increased the 'shrubbiness' of the vegetation.

Regular analysis of fire records provides a good basis for guiding the development of fire management policies and priorities. The analysis of fire cause for example can assist in targeting particular sources of fire (eg firing of boat flares and holiday-makers). The analysis of areas of fire origin will also assist in identifying off-Park sources of fire occurrence. The analysis of average wildfire size will also assist in identifying the success of prescribed burning and detection strategies. Fire frequency data (not analysed here) will also assist Park managers in determining the success of implementing certain fire management policies.

Despite doubts to the contrary by many groups, fuel reduced areas provide a real advantage to the achievement of fire regime prescriptions for natural areas and for locations considered to be significant and sensitive to changes in the fire regime. The implementation of strategic fuel management burns does assist in wildfire control even under extreme fire weather conditions in certain circumstances.

Fire records are an important source of information and the old records maintained by NPWS and Trust staff have proved to be particularly valuable in policy decisions today. This significance is often not recognised by land management agencies. The prescription of bushfires in an area must consider the wildfire history to be relevant and appropriate.

"To burn or not to burn"? — the answer is to burn, but to ensure that it is by prescription in accordance with management objectives and related strategies. Performance in achieving management objectives must be closely monitored and adequate records and maps kept of fire applications and fire effects.

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